CANADA

Department of Transport

PLANNING PEAK HOUR

R69-6

DETERMINATION AND
FORECASTING

Civil Aviation Branch

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DETERMINATION AND FORECASTING

Interim Report

Inquiries concerning the information in this report should be directed to W. S. Nasi, Aviation Research, telephone 992-1407.

PREPARED BY
AVIATION PLANNING AND RESEARCH DIVISION
CIVIL AVIATION BRANCH
DEPARTMENT OF TRANSPORT
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ABSTRACT

The purpose of this report was to develop a simple, inexpensive method for determining peak hour aircraft movements.

The method selects the busy hour by averaging a number of busy hours during the busy season for each airport. The value obtained approximates the 99th percentile.

The main advantage of this method is that it enables the planner to determine the peak hour for the airport several months before the end of the year, as most Canadian airports are summer busy.

PLANNING PEAK HOUR - DETERMINATION AND FORECASTING

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1.0 Planning Peak Hour

1.1 Introduction

Presently there are several methods used for selecting peak hour data for aircraft movements; therefore, some form of standard procedure would be desirable in order to provide more consistent and hence useful data within the Civil Aviation Branch. In pursuit of this end, the Civil Aviation Planning and Research Division of the Civil Aviation Branch prepared the following methodology for the Systems Planning Group Air, Statistical Sub-Committee.

The first part of this report deals with the method of determining the planning peak hour and contains a limited discussion of alternative methods. The second part considers the difficult subject of forecasting. In order to facilitate the initial forecasting of Planning Peak Hours, a method was developed for Systems Planning Air, Planning and Research Air Division. This method is a linear regression model in logarithmic equations and correlates Planning Peak Hours to aircraft movements. It should be stressed again that the method was prepared only as a means of implementing the first phase in forecasting Planning Peak Hours. It is assumed that later, when sufficient historical data on Peak Hours are available, alternate methods such as least square projections using linear, quadratic or log - log relationship or other forms of regression analysis should be attempted using the data for each individual airport.

Planning Peak Hour Methodology

1.2 The following methodology is suggested as a means of standardizing the technique for selecting peak hour data for aircraft movements from the type of statistics currently available from the Aviation Statistics Centre, Dominion Bureau of Statistics, Ottawa. A prime concern in the development of this method was that it would be relatively simple and hence inexpensive to use.

Generally only a small portion of the year's statistics are required to determine the planning peak hour, hence a valuable lead-time may be realized by not having to wait for the twelve months data summary at the end of the year.

The three highest months of the year by total aircraft movements on the airport are selected for analysis. The choice of the three months may be made by total itinerant movements at the discretion of the analyst to cover the case when the general aviation or local portion of the airport traffic is being considered for removal to another airport. This implies that the itinerant movements are the inflexible portion of the airport traffic and will therefore be the predominating factor in any proposed airport extension. Moreover, as the itinerant movements are comprised of what may be considered as extended locals, a considerable portion of the itinerant movements may be shifted to a general aviation airport as well.

The ten highest peak hour movements for each of the three months are accumulated and averaged. This average quantity

is called the Planning Peak Hour. Although this method tends to exclude the probability of selecting abnormally high peaks outside the three months interval and reduces the higher values within by the averaging process, the decision to remove or truncate a particularly high peak hour is again left to the analyst. The general approach here is to provide a flexible guide rather than a rigid formula.

Other Methods

1.3 Selecting a Particular Peak

Many agencies and/or states obtain peak hour figures by selecting a particular peak. As most of these methods are locally adcpted, references have been most difficult to locate. The following list is by no means complete and is included only to show the variance between selected peaks.

20th peak - Telephone Industry

27th peak - Ontario Department of Highways

30th peak - Department of Transport prior to the method proposed in this paper

30th peak - United Kingdom - Bureau of Trade

10% of the absolute peak

10% of the average daily traffic - A Study by the Technical University of Denmark.

The most serious objection to this method is that it places too much emphasis on a particular value. The selection of a particular peak assumes that a smooth continuous curve would

be in evidence if the data were plotted in the neighbourhood of the chosen peak. Should a discontinuity occur at the peak then we could either seriously overestimate or underestimate the peak conditions at the airport, depending upon whether the discontinuity occurred above or below the peak. Furthermore, this type of analysis can only be performed when the results from the entire year are compiled. This usually requires an extra computer run for the year or the use of considerable man hours. The Planning Peak Hour method should provide a more consistent and reliable estimate because it takes an average value.

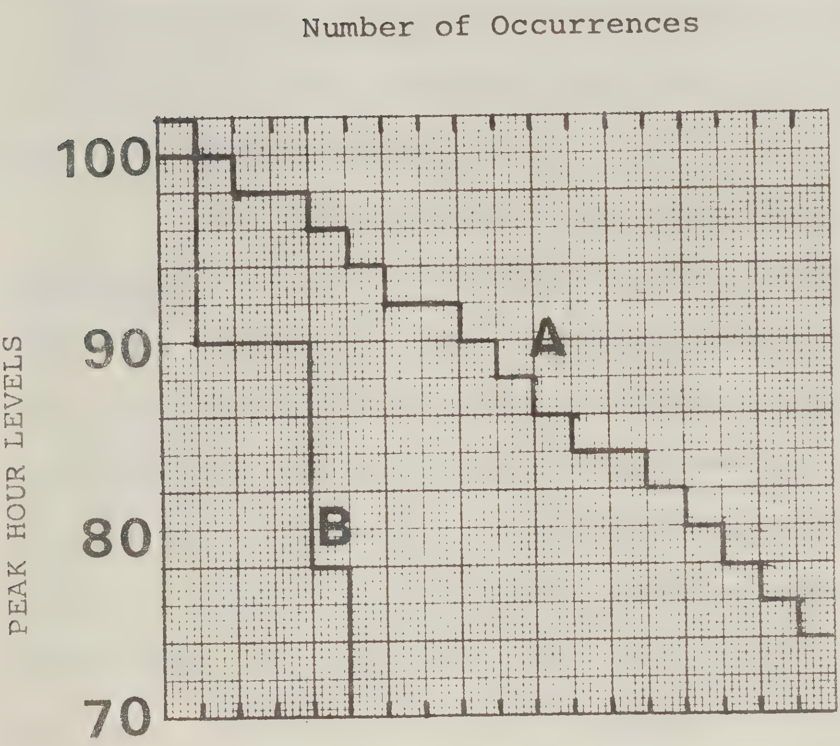
1.4 First Minima in Curve

This method attempts to find the position where the curve first begins to flatten out. The analyst examines each peak level beginning with the highest, and selects as the peak hour, that value which occurs a specified number of times. Unfortunately the method is highly dependent on the frequency distribution of the data and as such may be unreliable. To illustrate this possibility, consider two hypothetical airports with peak hours arranged in descending order such as that shown in Figure 1.

Figure 1

Plot of Peak Hours for

Hypothetical Airports A and B



If the criterion for frequency of occurrence for the peak hour were set at three or more observations, then the peak hour for B would be 90, while A's peak hour would be somewhere below 70 where the graphs have been terminated.

Examination of the graph shows that the value of 90 aircraft movements per hour occurred at least three times for B. The two observations at 98, 92 and 84 for A were not sufficient, within the above stated criterion, to be called a peak hour. It is evident that while heavier traffic is occurring at A, B would be given a higher peak hour using this method.

1.5 Percentile Method

This method accumulates peak hours starting with the largest until it represents a specified percentage of the total movements. Thus the 99th percentile would be the value of the peak hour that when added to the accumulation of equal or lower peak hours, totalled 99% of the total movements for the year. Figure 2 illustrates this method: Assume that a plot of cumulative peak hours were smoothed out and for convenience, the vertical scale was reduced such that the total was one. A value of X which represents .99 or 99% of the area, is called the 99th percentile.

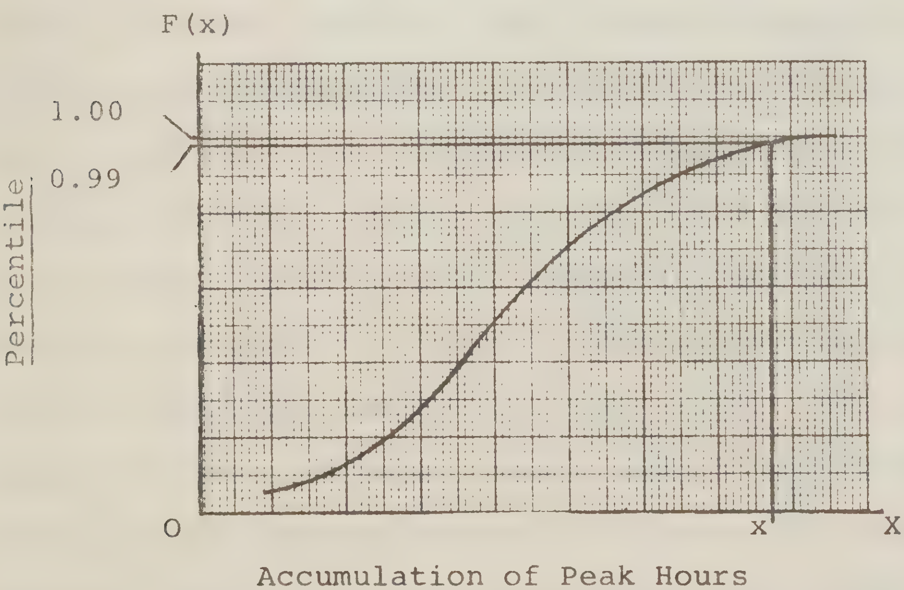


FIGURE 2: Determining a Percentile

The percentile method is a particularly valuable tool for determining the interrelationship between peak hours chosen by different methods. For example, if the 20th highest peak hour of the year for one airport and the peak hour chosen by taking 10% of the absolute peak hour for another were both representative of the 99th percentile then it would be meaningful to make comparisons between them.

Of course, if these values were taken from the same airport, both peak hours would be identical in this case.

An unfortunate disadvantage of the percentile method is that it does not resolve the problem of eliminating high abnormal peak hours. The accumulation of the 1% of movements that are above the airports' assigned peak level comprise most of the abnormally high peak hours that occurred during the year. Recall that the Planning Peak Hour method excluded the data for nine months of the year thereby eliminating some of them.

Abnormally high or "odd ball" days such as may occur at a fly-in, airshow, holidays, etc., always form part of the 1% and may produce an unacceptably high peak hour for the airport. It is conceivable that a single week of exceptionally high traffic at an airport outside the busy period, could determine the peak hour for the entire year with the percentile method. A solution to this problem would be to have a percentile that varied for each airport, depending upon the circumstances. The expense and complexity and cost in man hours could be substantial. The PPH method accomplishes this task because it would consider only ten high days from each of the busy months and average them. The result would probably be a lower value for the peak hour.

Further, as statistics are normally produced on a monthly basis, the use of the percentile method would require a rather costly recompilation of data for the entire year. The availability of planning peak hour data prior to the end of the year is of considerable value to planners both in lead time for short range modifications (taxi strips, etc.) and long range planning. Thus the method proposed earlier in this paper would be more advantageous in this context.

It may be desirable to develop a form of the percentile method at a later date that would only use a few months during the busy season. Such a system would be similar to the PPH method proposed in this paper and would undoubtedly provide a viable solution.

1.6 Analysis of Planning Peak Hour Method

In order to accomplish the analysis of the PPH method the data from twenty-five of the largest airports in Canada for 1968 were used. The source material was published by the Aviation Statistics Centre, Dominion Bureau of Statistics, Ottawa. The attached tables are generally self-explanatory, although several have additional remarks following them for clarity. Some of the comments on the PPH method and on the comparison between the PPH method and the percentile method were prepared for CAP by APS (System Planning Air, Planning and Research Air).

As the planning peak hour (PPH) approximates the 99.5th percentile, Tables 3 to 5 have been included to show the number of movements and percentage of hours above the peak. The Tables clearly show that the amount of movements above the peak are indeed substantial, e.g., 1,770 total movements occurred above the selected peak in Montreal. That is to say, if the capacity of the Montreal Airport were the same as the planning peak hour (i.e., at capacity) then 1,770 movements would be conducted beyond the calculated airport capacity over the year.

Current capacities for airports are calculated assuming a four minute average delay to departures. Even with a 4-minute delay, a small proportion of aircraft are experiencing delays as long as 20 minutes but very few are experiencing delays beyond 20 minutes as can be seen from the drawing in Figure 3. This was one of the reasons a 4-minute delay was chosen. The curve in Figure 3 represents a negative exponential function and is characteristic of the distribution of delay generally found in queuing problems.

When an increase in demand exceeds the practical capacity the average delay increases exponentially. The graph rises very sharply above the demand that produces an average delay of four minutes.

It can be seen from Figure 4 that a small increase in demand beyond capacity C, to A, leads to a very large increase in the average delay. A new average delay of t_A = 5 minutes would increase the delays much beyond 20 minutes for a proportion of the air carriers using the airport. If some of the excess demand were shifted to other airports then they in turn could be forced into higher delays if they were near capacity. This compounding effect could cripple a very large portion of the country such as when inclement weather along the Atlantic coast produces a greater demand on Montreal, Ottawa and Toronto. The following quotation was extracted from the Federal Aviation Administration's (FAA) News on 15 November, 1969.

> "Once an airport reaches its practical capacity, an increase in demand of just 15 percent can double the delays. If an airport fills up on the ground and in its holding patterns, bottlenecks begin to ripple through the system and before long we have a nationwide slowdown."

The above discussion was introduced to defend the rather high (99.5) percentile that the planning peak hour is representative of.

AVERAGE DELAY = 4.0 MINUTES

MAXIMUM DELAY = 20.5 MINUTES

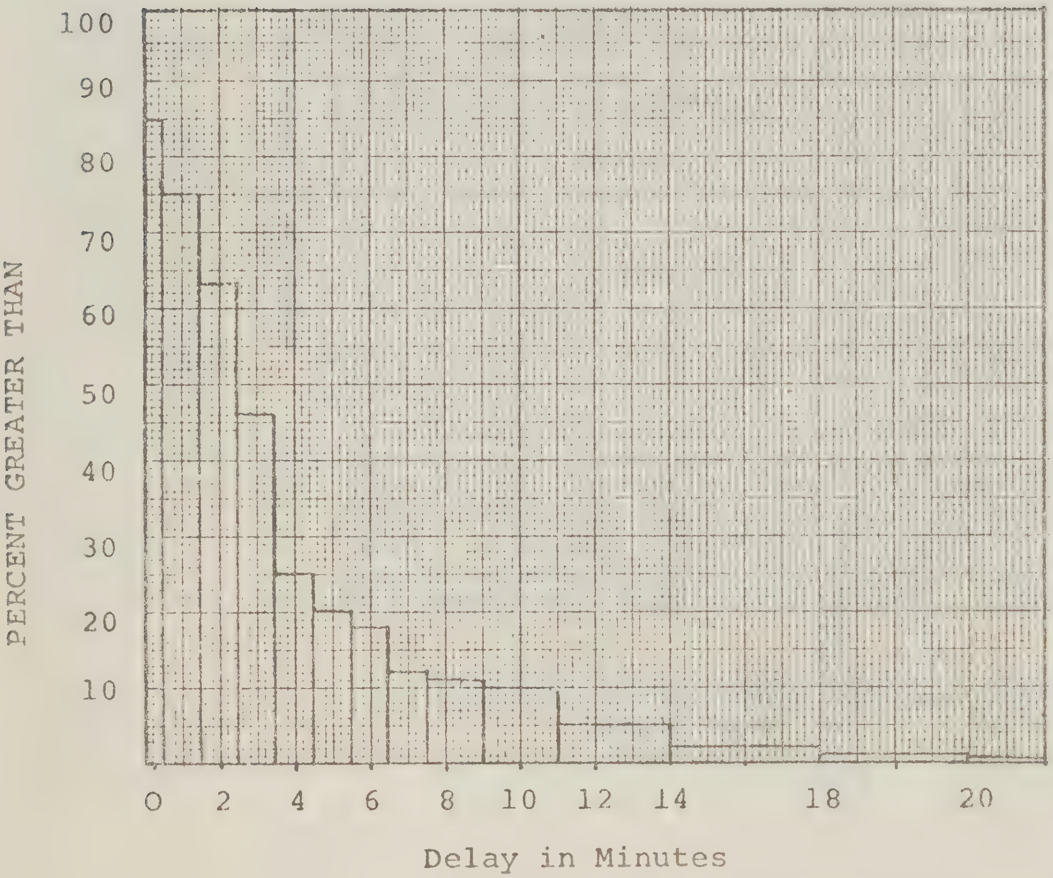


FIGURE 3: Distribution of Departure Delay

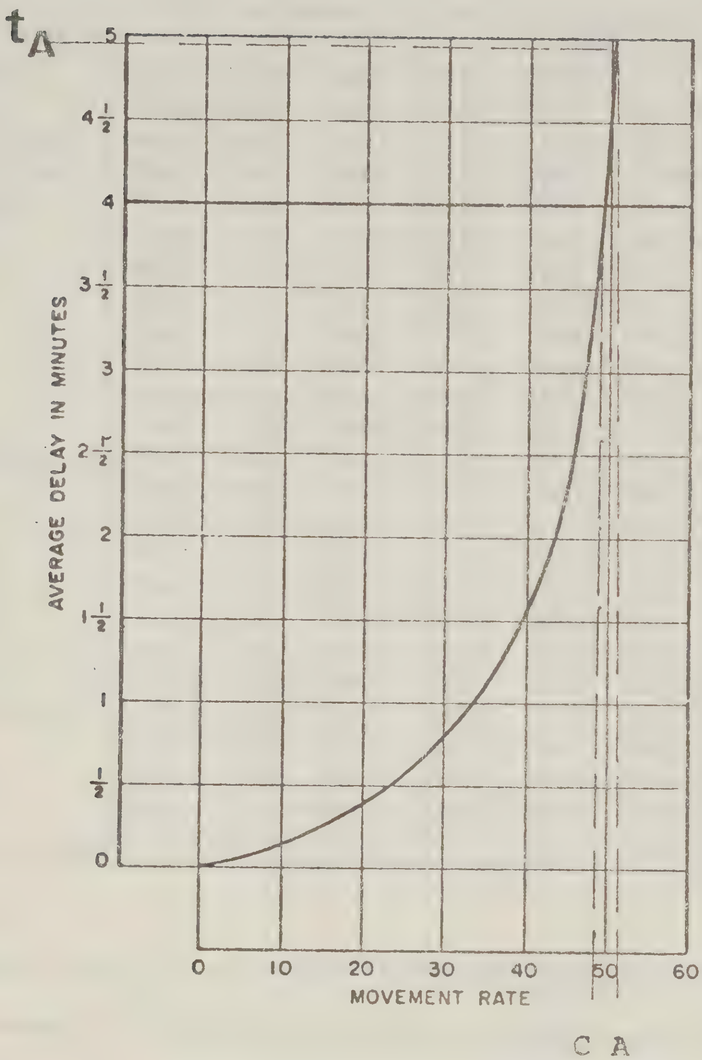


FIGURE 4: TYPICAL AVERAGE DELAY CURVE

1.7 TABLE 1

DATA FROM 1968

Airport Heavy Months, in order

	Total Movements			Itin.Movements			Local Movements		
Baie Comeau	Oct	Nov	May	July	May	Aug	Nov	Oct	Dec
Calgary	July	Mar	May	July	Aug	June	Mar	July	Feb
Edmonton Indus.	Mar	Apr	July	July	June	Apr	Mar	Apr	July
Edmonton Inter.	Apr	Mar	Feb	July	Aug	June	Apr	Mar	Feb
Fredericton	Feb	Apr	Mar	July	Aug	June	Feb	Mar	Apr
Gander	July	Aug	June	July	Aug	Sept	July	Aug	May
Halifax	May	July	Apr	July	Aug	May	May	July	Mar
Lakehead	Apr	Mar	Feb	Apr	June	May	Apr	Mar	Feb
London	July	Oct	Aug	July	Aug	Sept	July	Oct	June
Moncton	July	May	Apr	July	Aug	May	July	May	Apr
Montreal	July	Aug	May	Aug	July	May	July	Aug	May
Ottawa	Aug	July	June	May	Aug	Oct	Aug	July	Apr
Prince George	May	Aug	Mar	July	May	Aug	May	Mar	Sept
Quebec	Sept	Apr	July	Aug	July	Sept	Sept	Apr	Mar
Regina	July	June	Mar	July	June	May	July	Mar	Apr
Saskatoon	Mar	Feb	Oct	July	June	Aug	Mar	Feb	Oct
Saint John	May	July	Apr	May	July	Aug	May	July	Apr
St. John's	July	Jan	Sept	July	Sept	Aug	Jan	Feb	July
Sept-Iles	May	July	Aug	July	Sept	May	May	Apr	July
Sydney	July	Sept	Aug	July	Aug	Sept	July	Sept	Aug & May
Toronto Inter.	July	Aug	Sept	July	Aug	Sept	Feb	Apr	Sept
Vancouver	July	May	Aug	July	Aug	May	Jan	May	Apr
Victoria	July	Feb	Apr	July	June	May	July	Feb	Apr
Windsor	May	July	Nov	July	Aug	June	May	Nov	July
Winnipeg	July	Sept	Apr	July	June	Apr	Sept	July	Apr

Table 1 shows the three busiest months for each breakdown viz.

Total Movements, Itinerant Movements and Local Movements.

Table 2

Tally of number of times each month is found in busiest months for each type of movement.

	Total Movements	Itin. Movements	Local Movements
January	1	0	2
February	5	0	8
March	8	0	10
April	10	3	14
May	10	12	10
June	3	10	1
July	19	23	16
August	9	19	4
September	5	7	5
October	3	1	3
November	2	0	2
December	0	0	1

Table 2 shows that there are few times when October, November or December are peak months for traffic. Therefore, if estimates of planning peak hour movements were made after September's figures were in, we would be fairly certain that we had obtained the three heaviest months for each type of movement without looking at October, November or December. For total movements, we would be approximately 94% certain. For itinerant movements, we would be approximately 98% certain, and for local movements, we would be approximately 93% certain.

In practice each individual airport would be considered with reference to its past history. That is, if June, July and August were busy for several years and September was not a particularly busy month, then the planning peak hour could be computed in early September.

1.9 TABLE 3

TOTAL MOVEMENTS

1968

AIRPORT	Planning Peak Hour Movement	Peak Level	% of hours not covered by peak	# of movements not covered by peak forecast
Baie Comeau	29.4	25	.28	43.4
Calgary	107.8	43	.49	1099.1
Edmonton Indus.	105.2	59	.67	1388.0
Edmonton Inter.	39.6	28	.32	105.3
Fredericton	36.6	18	.20	49.8
Gander	74.1	21	.24	124.6
Halifax	72.0	25	.28	269.1
Lakehead	74.7	21	.24	223.0
London	81.8	58	.66	646.0
Moncton	64.0	26	.29	266.5
Montreal	96.8	66	.75	1770.8
Ottawa	106.2	74	.84	1530.5
Prince George	58.5	29	.33	177.5
Quebec	104.1	32	.36	401.0
Regina	83.1	37	.42	437.2
Saskatoon	86.3	17	.19	194.6
Saint John	60.9	47	.53	316.9
St. John's	22.2	24	.27	28.4
Sept-Iles	33.1	38	.43	144.5
Sydney	20.7	10	.11	13.5
Toronto Inter.	76.8	35	.35	649.6
Vancouver	58.7	83	.95	1413.6
Victoria	90.8	38	.43	504.4
Windsor	56.5	33	.37	216.8
Winnipeg	103.2	38	.47	1063.6

The last column shows that a considerable number of movements are occurring above the peak hour.

1.10 TABLE 4

ITINERANT MOVEMENTS 1968

Airport	Planning Peak Hour Movement	Peak Level	% of hrs not covered by peak	# of mvts out of total itin. mvt. which are over the peak
Baie Comeau	8.3	54	.61	69.5
Calgary	26.0	20	.22	142.6
Edmonton Indus.	34.6	97	1.10	908.6
Edmonton Inter.	9.9	55	.63	138.0
Fredericton	10.3	30	.34	56.8
Gander	15.6	26	.29	66.4
Halifax	19.4	38	.43	149.2
Lakehead	19.9	8	.01	2.8
London	22.5	79	.90	338.4
Moncton	15.3	16	.18	54.5
Montreal	42.1	34	.42	590.0
Ottawa	37.2	47	.53	462.7
Prince George	14.0	38	.43	92.5
Quebec	28.2	15	.17	83.0
Regina	22.1	31	.35	129.2
Saskatoon	17.2	80	.91	310.3
Saint John	15.1	36	.41	97.2
St. John's	6.0	29	.33	28.1
Sept-Iles	13.7	32	.36	77.8
Sydney	7.7	20	.22	19.4
Toronto	48.8	15	.17	260.6
Vancouver	46.7	57	.65	804.1
Victoria	25.4	88	1.01	502.0
Windsor	15.3	25	.28	63.6
Winnipeg	41.7	75	.87	950.0

1.11 TABLE 5

LOCAL MOVEMENTS

Airport	Planning Peak Hour Movement	Peak Level	% of peaks over peak hour level	# of mvts. of total mvts. expected to exceed peak hr. mvt. at level
Baie Comeau	27.5	20	.22	9.0
Calgary	83.8	101	1.14	1818.3
Edmonton Indus.	81.5	42	.47	550.4
Edmonton Inter.	24.1	30	.34	37.4
Fredericton	33.4	16	.18	14.8
Gander	61.4	25	.28	81.2
Halifax	58.1	21	.24	146.9
Lakehead	66.7	17	.19	124.3
London	69.0	53	.60	361.8
Moncton	56.9	23	.26	160.2
Montreal	50.9	52	.59	564.0
Ottawa	76.8	38	.43	408.0
Prince George	50.6	21	.24	78.0
Quebec	94.9	20	.22	137.7
Regina	74.3	24	.27	181.4
Saskatoon	72.5	20	.22	150.3
Saint John	49.4	49	.55	198.6
St. John's	17.6	20	.22	4.4
Sept-Iles	26.3	28	.32	38.4
Sydney	18.2	12	.13	4.6
Toronto	37.7	24	.27	87.2
Vancouver	43.5	30	.34	60.9
Victoria	72.1	32	.34	229.8
Windsor	48.1	29	.33	118.5
Winnipeg	74.9	40	.46	538.7

1.12 Planning Peak Hour Statistical Summary

When calculation of each planning peak hour movement was complete, the level of each in terms of total peaks for the whole year was found. The mean peak levels are shown below:

Type of Movement	Mean Peak Level	Standard Deviation
Total Movements	36.85	17.5
Itinerant Movements	41.35	24.5
Local Movements	32.65	17.5

From the previous tables, the mean percentile and Standard deviation for each of the three classes of movements were calculated.

Type of Movement	Mean Peak Level	Standard Deviation
Total Movements	99.58	.19
Itinerant Movements	99.53	.27
Local Movements	99.63	.19

Once the above percentages had been calculated, it was considered useful to know the number of aircraft expected to exceed the PPH of the airport during a year. The following data were calculated using the ratio technique.

Type of Movement	Mean # of Aircraft	Standard Deviation
Total Movements	523.1	515
Itinerant Movements	255.9	270
Local Movements	244.2	360

The excessive standard deviations result from an attempt to combine all the Canadian Airport data in one table.

If the airports studied are broken down in terms of size, and studied individually, certain differences in the effect of the method on different airports become apparent. The airports were broken into the standard groups of major hubs, large hubs, and medium hubs. It appears that the size of airport makes a difference in the effect of the method of calculation of peak hour movements. The figures are found below:

Size of Airport	Type of Movement	Peak Level	% Coverage
Major Hubs	Total Movements	63.6	99.32
	Itinerant Movements	35.3	99.60
	Local Movements	35.3	99.60
Large Hubs	Total Movements	44.5	99.49
	Itinerant Movements	55.3	99.37
	Local Movements	45.3	99.48
Medium Hubs	Total Movements	30.2	99.66
	Itinerant Movements	37.7	99.57
	Local Movements	25.8	99.71

It is evident that the best coverage is for medium hubs, and the worst coverage is for large hubs. Major hubs do not emerge all that well either. Since major and large hubs together control about 70% of total air traffic in Canada, their figures are the more significant.

The difference between different sized hubs in coverage shows up in the number of aircraft expected to exceed peak hour movement levels throughout the year.

Size of Airport	Type of Movement	Mean No. of A/C in excess
Major Hubs	Total Movements	1278.0
	Itinerant Movements	551.5
	Local Movements	238.7
Large Hubs	Total Movements	909.3
	Itinerant Movements	458.5
	Local Movements	583.3
Medium Hubs	Total Movements	236.7
	Itinerant Movements	127.4
	Local Movements	118.2

This shows once again that because of their lower percentile levels of coverage, there will be more occasions at major and large hubs where the number of aircraft being handled exceeds the planning peak hour movement than there will be at medium hubs. This is important when considering whether or not to accept the method. Critics who suggest that the percentile coverage under this method is unreasonably high should realize

that the airports to which this criticism is aimed are not the most important airports in Canada. The figures show that for large hubs and major hubs, the method does not give very unreasonably high results. An expected value of 909 aircraft in excess of planned peak hour movements throughout the year at a large hub is not unreasonably low; it is a substantial number of aircraft.

In summary, the method gives some rather high planning peak hour movement levels, especially in the medium hubs, but on the whole it gives values which are quite reasonable. In fact, as can be seen from the figures for mean peak level, it gives lower peaks than the old method of choosing the 30th absolute peak for the year as the planning peak hour movement. This method also has the advantage that we can make a pretty accurate estimate of the year's planning peak hour movement at the end of September of a given year, a possible saving of three months' time.

1.13 Abnormal Peak Values

Concern was expressed that extreme values of peak hour movements would influence planning peak hour movements unreasonably. It was suggested that these extreme values be rejected. Just how extreme a value would have to be to be rejected is uncertain, but somewhere in the neighbourhood of 20% difference was mentioned. Once the extreme values were removed, calculation would proceed as for the PPH method.

An examination was made of the peak hour movement data used in calculating by the PPH method, and any values which differed from their neighbours by 20% or more were eliminated.

It was found that in 13 airports, over half those studied, there were no values which differed by 20% or more, so their planning peak hour movements remain the same. For the remaining twelve, a table has been drawn up showing the old figure, the new figure, and the percent difference between them.

Previous articles on Peak Passenger Hour (PPH) have considered a 10% difference between peaks as being abnormal. The analyst will probably have to pick a value that he considers reasonable after careful study of the statistical data.

	Total Movements			Itin. Movements			Local Movements		
Airport	Old Peak	New Peak	% Diff	Old Peak	New Peak	% Diff	Old Peak	New Peak	% Diff
Baie Comeau	29.4	28.1	4.5	8.3	8.1	1.9	27.5	26.3	4.3
Calgary	107.8	107.0	0.7	26.0	26.0	0	83.8	82.7	1.3
Fredericton	36.6	36.0	1.6	10.3	10.3	0	33.4	32.8	1.1
Halifax	72.0	70.2	2.5	19.4	19.2	1.1	58.1	58.1	0
Ottawa	106.2	106.2	0	37.2	37.2	0	76.8	74.2	3.4
Quebec	104.1	104.1	0	28.2	28.2	0	94.9	94.4	0.9
Regina	83.1	81.6	1.7	22.1	22.1	0	74.3	73.0	1.8
Saskatoon	86.3	84.3	2.4	17.2	17.2	0	72.5	71.2	1.8
Sept-Iles	33.1	33.1	0	13.7	13.5	1.1	26.3	26.3	0
Sydney	20.7	20.7	0	7.7	7.7	0	18.2	17.7	3.0
Toronto	76.8	76.8	0	48.8	48.8	0	37.7	36.1	4.0
Vancouver	58.7	58.7	0	46.7	46.2	1.1	43.5	43.5	0

1.14 TABLE 6

1.15 Analysis of Table 6

As can be seen, the percent changes in planning peak hour movements caused by eliminating extreme values are not great.

Type of Movement	Mean % change of those airports which actually do change.	Mean % change of all airports
Total Movements	2.2	0.5
Itinerant Movements	1.3	0.2
Local Movements	2.4	0.9

The mean percent change for all airports is less than one percent for every type of movement as is evident in the table above. The lowest percent change is for itinerant movements, and the largest percent change is for local movements. Since itinerant movements usually predominate when considering extensions to major airports, the percent changes caused by eliminating these abnormal peaks are insignificant with this data.

However, the choice to remove or truncate unreasonably high peak hours is still considered a useful addition to the PPH method.

PLANNING PEAK HOUR MOVEMENT FORECASTS

2.0 Planning Peak Hour Movement Forecasts

2.1 Discussion of Linear Projections

A straight linear projection of peak hour movements by use of the ratio of air traffic now, to peak hour movements now is unrealistic and inflated in most cases. A table using selected airports as examples will illustrate this:

Airport	Total Mvts. 1968	Planning Peak Hr. Total Mvt 1968	Fcst Total Mvts 1986	Linear Fcst Planning Peak Hr. Total Mvt. 1986
Baie Comeau	15.5	29.4	186.8	355
Edmonton Inter.	32.9	39.6	852	1050
Ottawa	182.2	106.2	863	505
Prince George	53.8	58.5	343.9	373
Saskatoon	102.4	86.3	421.3	348
Victoria	117.3	90.8	652.3	506
Winnipeg	226.3	103.2	1395	636

Linear projections are accomplished by using the following formula:

$$\frac{X}{\text{Peak Hour Movement (NOW)}} = \frac{\text{Air Traffic Forecast}}{\text{Air Traffic (NOW)}}$$

The main reason for the inflated forecasts is that the equation overestimates the vertical growth of peak hour movements. Historical data shows that as air traffic increases, peaks spread more laterally than they do vertically [1]. Because of the increased waiting time at the initial peak hours, passenger demand and hence aircraft will begin to arrive and depart earlier or later to avoid waiting in queues.

1. It may be argued that the reason the peaks spread is because the physical construction of the airport restricts the growth that would be forecast by the linear projection. If this were true, then, assuming an extremely high

> capacity of 100 movements per hour, the peak hours forecast by the linear method would require at least five new airports in Winnipeg, four in Victoria, etc. Clearly this would be beyond the economic capabilities of this country and hence we cannot afford the luxury of the linear projection. An exception to this is when the forecast intervals are very short or where the curve is approximately straight; then the linear projection or ratio technique is usually sufficiently accurate for forecasting within a small time frame.

There will of course be an upward growth in absolute peak hour movements, but this growth will by no means cover the full expansion in air traffic. The remainder will be taken up by a lateral expansion of peak hours. Eventually, as an airport expands into a major international airport, the notion of one peak hour for the day will vanish as most hours will have roughly uniformly heavy traffic (curfew hours excluded). It is the question of finding out how much of the growth in air traffic goes into vertical peak hour movement increase, and how much into lateral spread, that is the crux of the problem.

Some examples of how peaks actually do grow and flatten out as traffic increases were required. A natural solution to this problem was to evaluate the data on all major Canadian airports for the year 1968 since these airports covered the spectrum in both peak hour movements and annual movements. When these figures were plotted on graphs, a definite relationship was found, as can be seen in graphs of Total Movements, Itinerant Movements, and Local Movements. The relationship, however, appeared to be currilinear rather than straight and a log-log equation was found to be best suited for the data which is listed in the following Table.

2.2 Data Summaries - 1968 Data

Data for graphs showing suggested relationship between growth in aircraft movements and increased peak hour movements.

Airport	(000) Total Mvts.	Peak T.M.	(000) Itin. Mvts.	Peak I.M.	(000) Local Mvts.	Peak L.M.
Baie Comeau	15.5	29.4	11.4	8.3	4.1	27.5
Calgary	224.3	107.8	64.8	26.0	159.5	83.8
Edmonton Indus.	199.7	105.2	82.6	34.6	117.1	81.5
Edmonton Inter.	32.9	39.6	21.9	9.9	11.0	24.1
Fredericton	24.9	36.6	16.7	10.3	8.2	33.4
Gander	51.9	74.1	22.9	15.6	29.0	61.4
Halifax	96.1	72.0	34.7	19.4	61.2	58.1
Lakehead	92.9	74.7	27.5	19.9	65.4	66.7
London	97.9	81.8	37.6	22.5	60.3	69.0
Moncton	91.9	64.0	30.3	15.3	61.6	56.9
Montreal	236.1	96.8	140.5	42.1	95.6	50.9
Ottawa	182.2	106.2	87.3	37.2	94.9	76.8
Prince George	53.8	58.5	21.5	14.0	32.5	50.6
Quebec	111.4	104.1	48.8	28.2	62.6	94.9
Regina	104.1	83.1	36.9	22.1	67.2	74.3
Saskatoon	102.4	86.3	34.1	17.2	68.3	72.5
Saint John	59.8	60.9	23.7	15.1	36.1	49.4
St. John's	10.5	22.2	8.5	6.0	2.0	17.6
Sept-Iles	33.6	33.1	21.6	13.7	12.0	26.3
Sydney	12.3	20.7	8.8	7.7	3.5	18.2
Toronto Inter.	185.6	76.8	153.3	48.8	32.3	37.7
Vancouver	148.8	58.7	129.7	46.7	19.1	43.5
Victoria	117.3	90.8	49.7	25.4	67.6	72.1
Windsor	58.6	56.5	22.7	15.3	35.9	48.1
Winnipeg	226.3	103.2	109.2	41.7	117.1	74.9

2.3 Use of Graphs in Forecasting

Three graphs have been provided to give the Planning Peak Hour (PPH) for Total Movements, Itinerant Movements and Local Movements. The latter graph has a low index of determination (.86) due to the unpredictable nature of local flying. It should therefore be used with caution.

Because the peak hours for each of these three graphs are not necessarily coincident, one must be careful when making comparisons between them. That is, if the Itinerants peaked at say 1600 hours and the locals at 1800 hours, it is possible that the total movements could peak at say 1700 hours. Direct summations or comparisons between the graphs are therefore unwise due to the possibility of non coincidence.

Forecasting technique

(1) Select the proper graph for use.

(2) Read the forecast number of movements along the horizontal axis for the year that the peak hour is required.

(3) Where the vertical line from the forecast number of movements intersects the straight line (an equation in logarithms), read the planning peak hour movements shown on the vertical scale.

2.4 Basic Assumption

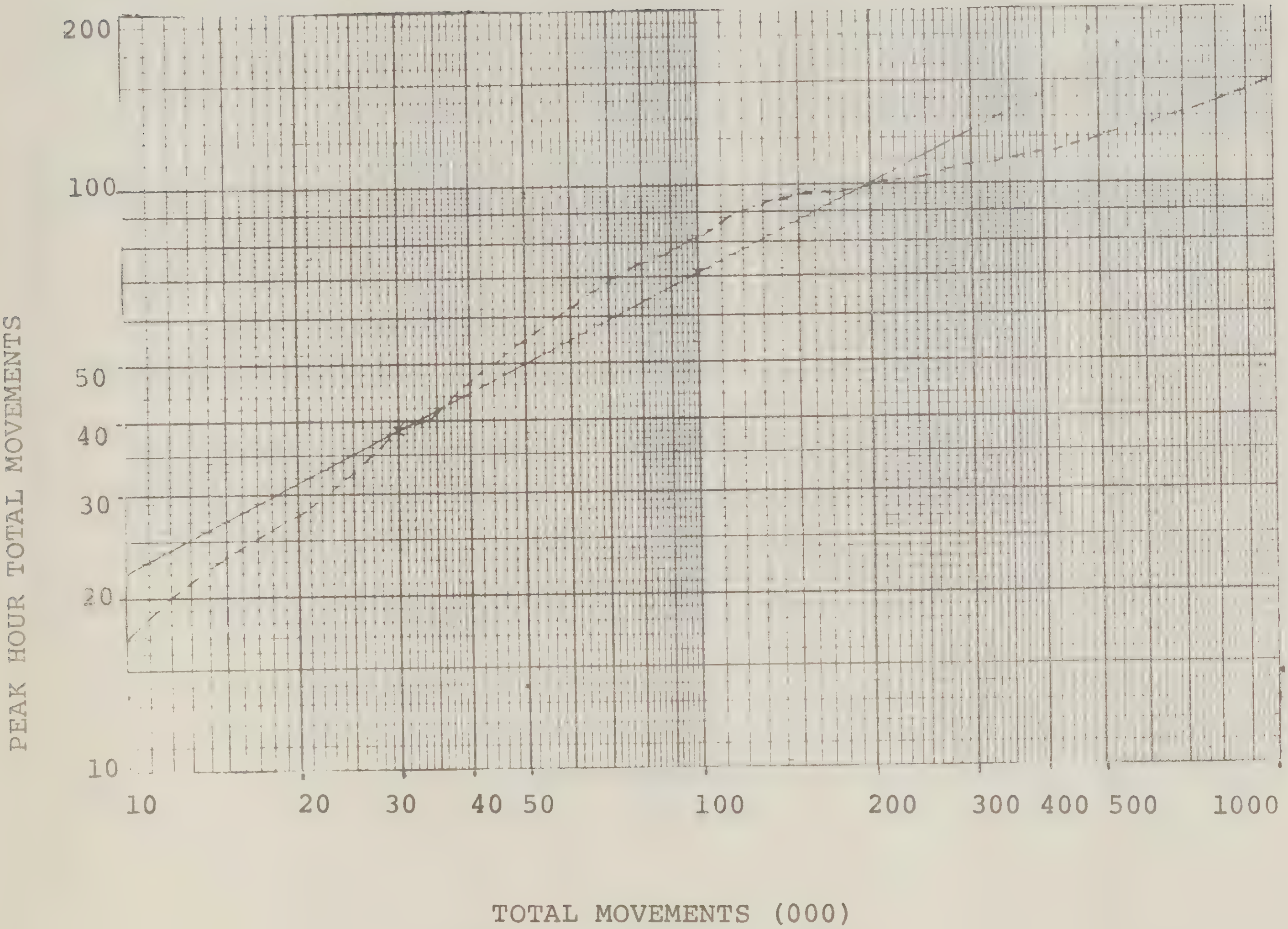
The basic assumption of the forecast peak condition is somewhat circular in nature, an explanation of which is given below.

(1) Since the curves were produced from a cross section of airports in Canada, the forecast peak assumes that the future expansion to any airport will continue to be built with the same technology as in the past. That is, when an expansion to an airport such as Seven Islands is carried out, it will <u>not</u> be brought up to the standards of say Montreal International. For if it were, we could expect the peak hour to be much higher even with a lower total annual movements. The rationale here is that any build up for say noon hour flights could grow unrestricted to a higher limit due to the greater capacity of an airport such as Montreal over that of Seven Islands. Because of economic restrictions we expect that the expansion of an airport would resemble an airport which has a slightly greater capacity for some greater total annual movements.

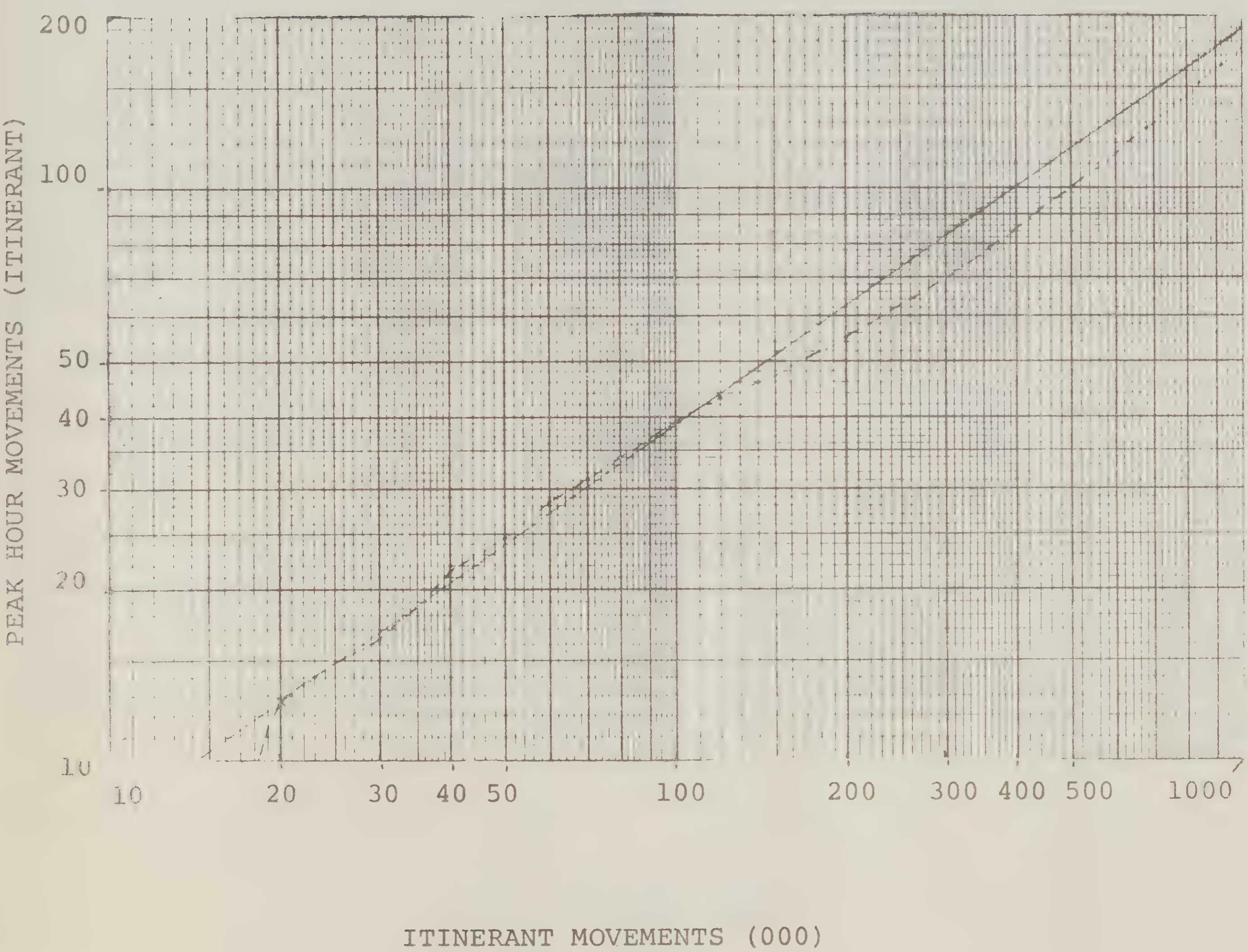
2.5 <u>Computer Program</u>

Copies of the computer runs from the remote time sharing facilities in DOT Headquarters are attached for convenience. The program used here is MULFT $***. It is a flexible program that allows the operator the ability of trying linear, quadratic or log-log equations to obtain a best fit by the least square method. The index of determination for each equation is given and may be thought of as the number (in tenths) of points on the graph that can be satisfactorily estimated using the equation. Generally, values above .8 are considered to be good fits while those below .8 are poor and should only be used with extreme caution.

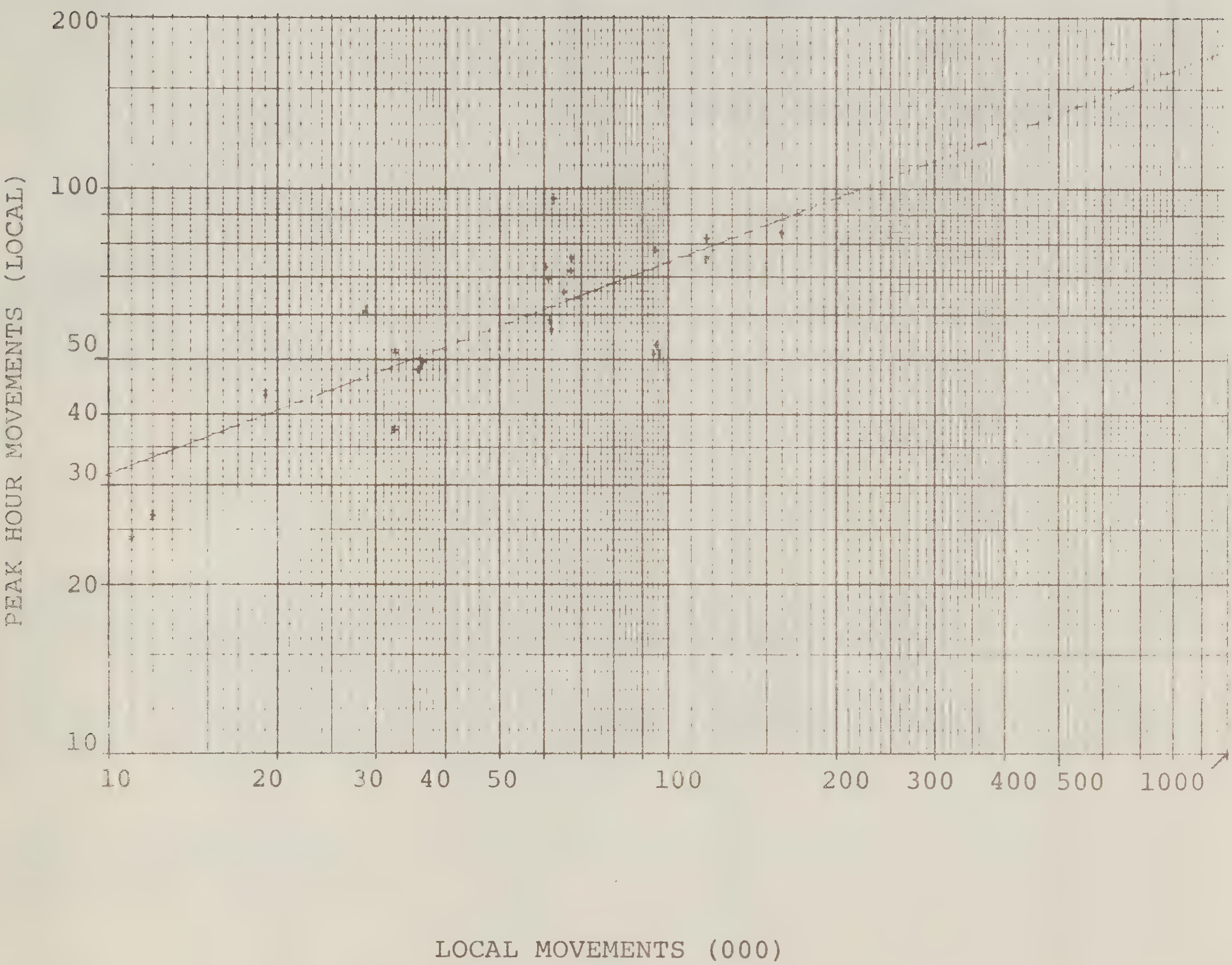
2.6 Planning Peak Hour Total Movement Growth Rate



2.7 Planning Peak Hour Itinerant Movement Growth Rate



2.8 Planning Peak Hour Local Movement Growth Rate



```
 DATA 25,2,2
00 DATA 29.4,107.8,105.2,39.6,36.6,74.1,72.0,74.7,81.8,64.0
01 DATA 96.8,106.2,58.5,104.1,83.1,86.3,60.9,22.2,33.1,20.7
02 DATA 76.8,58.7,90.8,56.5,103.2
00 DATA 15.5,224.3,199.7,32.9,24.9,51.9,96.1,92.9,97.9,91.9
01 DATA 236.1,182.2,53.8,111.4,104.1,102.4,59.8,10.5,33.6,12.3
02 DATA 185.6,148.8,117.3,58.6,226.3

000 LET Y = LOG (V(1))
001 LET X(1) = LOG (V(2))
 DATAB← 25,2,1

OT RDC OTTAWA

GE TIME-SHARING SERVICE

N AT  11:15   MTL TH 06/05/69   TTY 13

SER NUMBER--M32023
YSTEM--BAS
EW OR OLD--OLD
LD FILE NAME--MULFTS***
AIT.

EADY.

APE
EADY.

 DATA 25,2,2
00 DATA 29.4,107.8,105.2,39.6,36.6,74.1,72.0,74.7,81.8,64.0
01 DATA 96.8,106.2,58.5,104.1,83.1,86.3,60.9,22.2,33.1,20.7
02 DATA 76.8,58.7,90.8,56.5,103.2
00 DATA 15.5,224.3,199.7,32.9,24.9,51.9,96.1,92.9,97.9,91.9
01 DATA 236.1,182.2,53.8,111.4,104.1,102.4,59.8,10.5,33.6,12.3
02 DATA 185.6,148.8,117.3,58.6,226.3

000 LET Y = LOG (V(1))
001 LET X(1) = LOG (V(2))
 DATAB← 25,2,1
EY
EADY.

UN
```

TOTAL MOVEMENTS

Y = PPH Movements Total
X = Total Movements

Log - Log (to base e)

$\text{Log } Y = 1.95587 + 0.507132 \text{ Log } X$

LFTi 11:17 MTL TH 06/05/69 TOTAL

RSION OF 09/03/1968

RIABLE	REGR COEFF	MEAN VALUE	STD DEV
	1.95587	4.14469	.493723
	.507132	4.31608	.914472

URCE OF RIATION	DEGREES OF FREEDOM	SUM OF SQUARES	MEAN SQUARE
TAL	24	5.8503	.243763
GRESSION	1	5.16171	5.16171
ROR	23	.688597	.029939

DEX OF DETERMINATION: .882297
RATIO TEST STATISTIC: 172.407

TUAL	CALCULATED	DIFFERENCE	PCT DIFFER
.38099	3.34583	-3.51598E-02	-1
.68028	4.70096	2.06858E-02	.4
.65586	4.64205	-1.38123E-02	-.2
.67883	3.72752	4.86895E-02	1.3
.60005	3.58623	-1.38189E-02	-.3
.30542	3.95869	-.346723	-8.7
.27667	4.27112	-5.54480E-03	-.1
.31348	4.25395	-5.95331E-02	-1.3
.40428	4.28053	-.123745	-2.8
.15888	4.24846	8.95754E-02	2.1
.57265	4.72696	.154318	3.2
4.66532	4.59554	-6.97828E-02	-1.5
.06903	3.97693	-9.21004E-02	-2.3
.64535	4.34604	-.299308	-6.8
.42004	4.31167	-.108372	-2.5
4.45783	4.30332	-.154507	-3.5
.10923	4.03055	-7.86867E-02	-1.9
3.10009	3.14833	4.82328E-02	1.5
3.49953	3.7382	.238662	6.3
3.03013	3.22857	.198432	6.1
4.3412	4.60492	.263713	5.7
.07244	4.49285	.420406	9.3
.50866	4.37222	-.136444	-3.1
.03424	4.02027	-1.39743E-02	-.3
4.63667	4.70547	6.87965E-02	1.4

AN 12.33 SEC
YE

** OFF AT 11:21 ELAPSED TERMINAL TIME = 5 MIN.

```
DATA 25,2,1
00 DATA 8.3,26.0,34.6,9.9,10.3,15.6,19.4,19.9,22.5,15.3,42.1
01 DATA 37.2,14.0,28.2,22.1,17.2,15.1,6.0,13.7,7.7,48.8
02 DATA 46.7,25.4,15.3,41.7
00 DATA 11.4,64.8,82.6,21.9,16.7,22.9,34.7,27.5,37.6,30.3,140.5
01 DATA 87.3,21.5,48.8,36.9,34.1,23.7,8.5,21.6,8.8,153.3
02 DATA 129.7,49.7,22.7,109.2
```

ITINERANT MOVEMENTS

Y = PPH Movements (Itinerant)
X = Itinerant Movements

Log - Log (to base e)

$\text{Log } Y = 0.472809 + 0.693199 \text{ Log } X$

```
000 LET Y = LOG (V(1))
001 LET X(1) = LOG (V(2))

OT RDC OTTAWA


V

 !. (XT VICE

N AT  11:33   MTL TH 06/05/69   TTY 10

SER NUMBER--M32023
YSTEM--BAS
EW OR OLD--OLD
LD
LD FILE NAME--MULFT$***
AIT.

EADY.

APE
EADY.


 DATA 25,2,1
 00 DATA 8.3,26.0,34.6,9.9,10.3,15.6,19.4,19.9,22.5,15.3,42.1
 01 DATA 37.2,14.0,28.2,22.1,17.2,15.1,6.0,13.7,7.7,48.8
 02 DATA 46.7,25.4,15.3,41.7
200 DATA 11.4,64.8,82.6,21.9,16.7,22.9,34.7,27.5,37.6,30.3,140.5
201 DATA 87.3,21.5,48.8,36.9,34.1,23.7,8.5,21.6,8.8,153.3
202 DATA 129.7,49.7,22.7,109.2


 000 LET Y = LOG (V(1))
 001 LET X(1) = LOG (V(2))
RUN
```

LFTS   11:35   MTL TH 06/05/69   2.10   ITINERANT

RSION OF 09/03/1968

RIABLE	REGR COEFF	MEAN VALUE	STD DEV
	.472809	2.9581	.583593
	.693199	3.58524	.824096

URCE OF RIATION	DEGREES OF FREEDOM	SUM OF SQUARES	MEAN SQUARE
TAL	24	8.17393	.34058
GRESSION	1	7.83217	7.83217
ROR	23	.341752	1.48588E-02

DEX OF DETERMINATION: .95819
RATIO TEST STATISTIC: 527.108

CTUAL	CALCULATED	DIFFERENCE	PCT DIFFER
2.11626	2.15979	4.35321E-02	2.
3.2581	3.36435	.106258	3.1
3.54385	3.5326	-1.12571E-02	-.3
2.29253	2.61236	.319824	12.2
2.33214	2.42445	9.23039E-02	3.8
2.74727	2.64331	-.103961	-3.9
2.96527	2.93141	-3.38673E-02	-1.1
2.99072	2.7702	-.22052	-7.9
3.11352	2.98705	-.12647	-4.2
2.72785	2.83741	.109561	3.8
3.74005	3.90082	.160775	4.1
3.61631	3.57096	-.04535	-1.2
2.63906	2.59958	-3.94768E-02	-1.5
3.33932	3.16778	-.171542	-5.4
3.09558	2.97402	-.12156	-4
2.84491	2.91931	7.44054E-02	2.5
2.71469	2.66711	-4.75812E-02	-1.7
1.79176	1.9563	.164542	8.4
2.6174	2.6028	-1.45985E-02	-.5
2.04122	1.98035	-6.08754E-02	-3
3.88773	3.96126	7.35316E-02	1.8
3.84374	3.84538	1.63383E-03	0
3.23475	3.18045	-.054301	-1.7
2.72785	2.63723	-9.06232E-02	-3.4
3.7305	3.72612	-4.38321E-03	-.1

AN   12.17 SEC
YE

** OFF AT 11:39   ELAPSED TERMINAL TIME =   5 MIN.

LOCAL MOVEMENTS

Y = PPH Movements Local
X = Local Movements

Log - Log (to base e)

$$\text{Log } Y = 2.56233 + .382513 \text{ Log } X$$

```
OT RDC OTTAWA

GE TIME-SHARING SERVICE

N AT  14:21   MTL MN 12/29/69   TTY 13

SER NUMBER--M32023

PROJECT ID---WNTEST
SYSTEM--BAS
NEW OR OLD--OLD
OLD FILE NAME--MULFTS***


READY.

TAPE
READY.

 DATA 25,2,1
100 DATA 27.5,83.8,81.5,24.1,33.4,61.4,58.1,66.7,69.0,56.9,50.9
101 DATA 76.8,50.6,94.9,74.3,72.5,49.4,17.6,26.3,18.2,37.7,43.5
102 DATA 72.1,48.1,74.9
200 DATA  4.1,159.5,117.1, 11.0,  8.2, 29.0, 61.2, 65.4,60.3,61.6
201 DATA 95.6,94.9,32.5,62.2,67.2,68.3,36.1,2.0,12.0,3.5,32.3
202 DATA 19.1,67.6,35.9,117.1
1000 LET Y=LOG(V(1))
1001 LET X(1)=LOG(V(2))
0 DATA 25,2,1
RUN
```

RIABLE	REGR COEFF	MEAN VALUE	STD DEV
	2.56233	3.9055	.484679
	.382513	3.51142	1.17666

URCE OF RIATION	DEGREES OF FREEDOM	SUM OF SQUARES	MEAN SQUARE
TAL	24	5.63793	.234914
GRESSION	1	4.86187	4.86187
ROR	23	.776058	3.37417E-02

DEX OF DETERMINATION: .862351
RATIO TEST STATISTIC: 144.091

TUAL	CALCULATED	DIFFERENCE	PCT DIFFER
.31419	3.10206	-.212131	-6.8
.42843	4.50246	7.40256E-02	1.6
.4006	4.38426	-.016347	-.3
.18221	3.47956	.297349	8.5
.50856	3.36719	-.141362	-4.1
.11741	3.85037	-.26704	-6.9
.06217	4.13605	7.38847E-02	1.7
.2002	4.16144	-3.87653E-02	-.9
.23411	4.13038	-.103723	-2.5
.0413	4.13854	9.72469E-02	2.3
.92986	4.30666	.376798	8.7
.3412	4.30385	-3.73547E-02	-.8
.92395	3.89395	-2.99967E-02	-.7
.55282	4.14225	-.410574	-9.9
.30811	4.17183	-.136286	-3.2
.28359	4.17804	-.105551	-2.5
.89995	3.93414	3.41886E-02	.8
.8679	2.82747	-4.04268E-02	-1.4
.26957	3.51284	.243275	6.9
.90142	3.04153	.140111	4.6
.62966	3.89159	.261934	6.7
.77276	3.69063	-8.21317E-02	-2.2
.27805	4.1741	-.103959	-2.4
.87328	3.93201	5.87317E-02	1.4
.31615	4.38426	6.81021E-02	1.5

SED 11.83 SEC.
E

* OFF AT 14:28 ELAPSED TERMINAL TIME = 6 MIN.